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RESEARCH ARTICLE OPEN ACCESS

Protection Devices

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ABSTRACT
One of the most important parts of any electrical network is the protection devices.it used in a small or large networks. We will discuss three main and famous types in which they are commonly used in all networks. We concentrate on the principle of their operation and not exposed to the selection methods of them
Keywords – Protection device, fuses, circuit breaker, overcurrent device, relays

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I. INTRODUCTION

Protection devices used to protect two main things, the human from any electric shock and any electrical element or device from any damage caused by the heavy load or short circuit. The principles of protection are to disconnect and isolate the faulty part of the system. The protection devices, differs according to the type of the load or the electrical equipment's or the cables which intended to be protected, for examples, Motor – Generator – Cable …. Etc., We are going to discuss in this written subject only the protection devices which are used for a common electrical equipment (more than one electrical equipment). But before that we will mention the list for the protective devices used generally in the electrical systems and network..

1.1 main protection devices used in electric networks.
1- Fuses, power or control
2- Circuit Breakers
3- over load device
4- over current devices
5- under current devices
6- over voltage device
7- under voltage device
8- Earth fault device
9- differential protection
10- over temperature protection
11- reverse power protection (RP)
12- over pressures protection
13- Negative phase sequence protection (NPS)
14- over frequency
15- under frequency
16- field failure
17- diode failure 18- over speed.
19- and there are some protection devices related to other electrical equipment's.

1.2 main electrical elements or equipment's available in the electrical networks.
1- Generators.
2- Cables and transmission lines.
3- Transformers.
4- Motors
5- Heaters 6- Lights.

II. FUSES, CIRCUIT BREAKERS AND OVERCURRENT DEVICES

We discuss in detail the main protection devices, fuses, circuit breakers and overcurrent device.

2.1 FUSES

Mainly, fuses consist of a metallic wire or metallic strip. If the current exceeds above certain value the fuse cuts off the path of the current in the circuit. It has two types of currents, a normal current rating (service current) and a breaking current rating (maximum fault current). There is often confusion between the normal current and breaking current ratings of a fuse. The normal current rating is depending on the load and is the maximum value of current; the fuse can carry continuously without fusing or retrograde. The braking rating is the maximum protective current that the fuse can safely interrupt at its rated voltage. Usually, it is noted in kilo amperes (KA) RMS balanced and relevant to the system fault level.

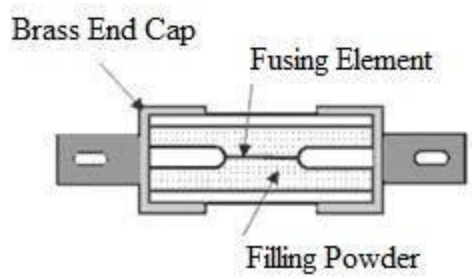

Fig 1.1

2.2 Circuit Breakers

Circuit breakers are one of the most important parts of high and low voltage networks. These circuit breakers used to protect and secure generators, feeders, and transformers in electrical networks. It is necessary for normal operation purposes and for disconnecting in the event of a short circuit or disconnection from active checks. Circuit breakers are divided in terms of voltage into three parts, low voltage circuit breaker (LV), medium voltage circuit breaker (MV) and high voltage circuit breaker (HV).

First, The low voltage circuit breaker is divided into automatic circuit breaker and manual circuit breaker. It is used to protect the electrical loads and people from the danger of electric current as a result of a short circuit or an increase in the loads. The circuit breakers are based on three technologies. Thermal, magnetic and differential, and these technologies are either combined in one circuit breaker or a single breaker contains one of them, and this depends on the type of breaker. The thermal breaker is used against increase the load, the magnetic is used against short circuit and the differential to protect the human from electrical current leakage. The circuit breaker type of the disconnecting mechanism is divided into five types of current. Miniature circuit breaker (MCB), automatic circuit breaker (MCCB), magnetic leakage circuit breaker (ELCB), differential circuit breaker (RCD), air current circuit breaker (ACB). Miniature circuit breakers (MCB). It works by thermal or magnetic separation or both, it can be reconnected manually after removing the fault and has a rapid response when an electrical short occurs and contains methods to quench the electric arc generated when the circuit is disconnected and is characterized by its efficiency and ease of installation. There are four types of them: single, double, triple and quadruple partitions. The thermal-magnetic breaker(as figure 1.2) consists of the operating knob for manual disconnecting and reconnecting, and the position of the switch indicates
the position of the connection or disconnection and most of the breaker are designed so that the knob works on manual disconnection in the event of non-response to the automatic disconnection due to electrical faults. The contacts serve to connect the voltage from the source to the load. Fixing screws connect the terminals of the voltage source on one side and the terminals of the load on the other side. Thermocouple and thermal protection in the breaker. Calibration screw and the rated current of the.

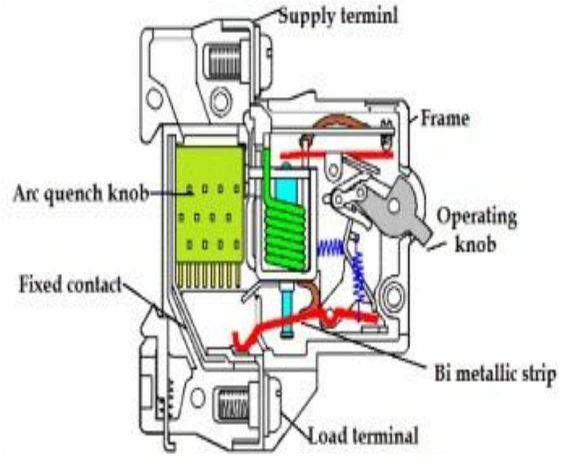

Fig 1.2

breaker shall be determined and calibrated by the manufacturer. The electromagnetic coil provides the magnetic protection for the breaker. The damper works to absorb the heat produced by the electric arc when the breaker is disconnected due to an increase in current or shortness. The following figure show miniature/ circuit breakers(MCB)

Fig 1.3

MCCB molded circuit breaker. It is considered an electrical protection device that is used when the current load exceeds the limit of the miniature circuit breaker. The MCCB provides protection against overload and short circuit faults. It can be used in industrial applications. The MCCB can be used to protect the capacitor bank, generator, and distribute the main supply. It provides adequate protection when an application requires discrimination, adjustable overload adjustment, or earth fault protection. a comparison between the ratings of modulated case circuit breakers MCCB and the miniature circuit breakers MCB described in the tables.

MCCB

Normal current	Breaking |Capacity to BS \Rule		
	MVA (3-phase, 440V)	Equiv. KA(a.c.) (rms symmetrical)	KA (d.c. 250V)
125 A	7.5 MVA	10kA	18 kA
250 A	15 MVA	20kA	25kA

Table 1: MCCB circuit breaker

MCB 70 A size

Trip Unit	Breaking Circuit (kA)			
	250V a.c		440V a.c	125V d.c
	1-pole	2-pole	3-pole	2-pole
3A	1kA	1kA	1kA rms symm(=0.75MVA)	1kA
6A	1kA	1kA	1kA rms symm(=0.75MVA)	1kA
10A	5kA	8kA	5kArms symm(=3.8MVA)	10kA
16 to 70A	5kA	8kA	3kA rms symm(=2.3MVA)	10kA

Table 2: MCB 70 A size

MCB 32 A size

Trip Unit	Breaking Circuit (kA)			
	250V a.c		440V a.c	125V d.c
	1-pole	2-pole	3-pole	2-pole
	6kA	10kA	3kA rms symm(=2.3MVA)	5kA
1 to 5A	6kA	8kA	3kA rms symm(=2.3MVA)	5kA
10 to 32A				

Table 3: MCB 32 A size

Second, the high-voltage circuit breakers are divided into two main parts, namely, Oil Circuit Breaker. Oil circuit breakers are the most used externally for voltage (34.5Kv-360Kv) due to their economic cost. The oil breakers are divided into low oil breakers and full oil breakers. From (4.6KV - 34.5KV) in Indoor applications and From (14.4KV - 765KV) in Outdoor applications. In addition, the currents carried by these circuit breakers range between (630A - 3000A) and above. Full oil breakers are called full oil breakers due to the use of oil in them as an insulating medium in which the connection and separation operations of the points (connection terminals) are carried out. The uses of oil are limited here for two reasons. Amidst the extinguishing of the electric spark and is considered as an insulating material, as the separation and connection processes take place inside a steel tank, and the gases formed as a result of the high temperature resulting from the expansion of the electric spark, and where the following takes place: Spark cooling processes where the heat formed in the form of gases is expelled Operations of vortic turbulence of the oil movement. Gases compressed with high pressure have great insolation. As for the non-oil circuit breakers (Oil Less Circuit Breaker), the non-oil circuit breakers are considered one of the most used types in indoor applications. These circuit breakers are used at efforts whose values range between (1KV - 800KV), and depend on compressed air and a sixth gas Sulfur ide from outside stations at voltage (34.5KV - 362KV).) There are several reasons for using non-oil cutters, the most important of which are the following, removing the dangers of oil fires, eliminating the use of oil boxes and packing them, cleaner than others. Low maintenance. It has high-speed performance. It has the ability to withstand super voltages, more than 800KV. The non-oil circuit breaker is divided into vacuum circuit breaker and pneumatic driven cutter. Sulfur Six Fluoride Cutters (SF6) First: Vacuum Circuit Breaker This type is mainly composed of a room in which the degree of vacuum operates to less than (10-7 mm Hg) and contains two contacts, one of which is fixed and the other is movable and sealed between a rod The moving contact and chamber body by stainless steel bellows. Second: Air-Blast Circuit Breaker This type of circuit breaker is widely used in the requirements of indoor high voltage circuits for stations (Indoor). In outdoor applications, voltages whose values range between (34.5KV - 800KV) are used, but they are used in Some special purposes such as: generator circuit breakers with current rates of up to (24KV) and above. In electric furnaces, they are used as a single or three-pole breaker for traction and draft systems. Their ability to cut global currents. These circuit breakers are divided into two parts, namely: indoor pneumatic thrust circuit breakers (indoor) outdoor air-exposed circuit breaker (outdoor) Third: sulfur hexafluoride circuit breaker (SF6 circuit breaker) called sulfur hexafluoride cutter due to the use of sulfur hexafluoride gas as quenching medium for electric arc This circuit breaker is symbolized as a breaker (SF6 CB) and operates at voltages ranging between (14.4Kv-765Kv) as well as rated current up to (A 4000).

2.3 Over current protection relays, which can cover both fault and overload protection, are mainly related to heating effects in, and in some cases, electromechanical forces on, electrical conductors. Overcurrent devices come in a range of shapes and sizes, despite the fact that they all need an excess of current to function.

2.3.1 Instantaneous Over current (OC).

An instantaneous overcurrent relay is shown in Figure below

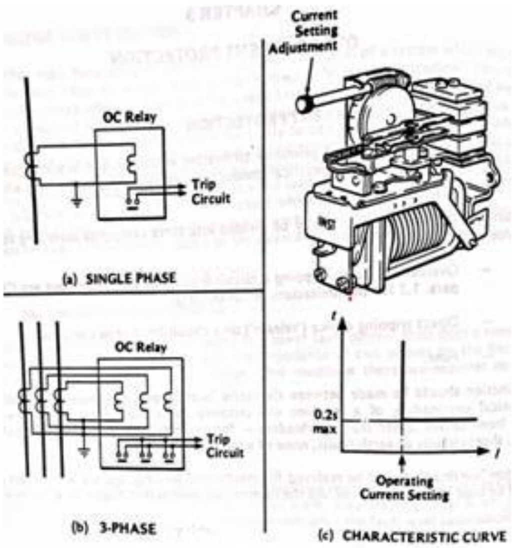

Fig 1.4

It is made up of a simple iron armature that is drawn in by a coil carrying current from a line current transformer and is returned to its rest position by gravity or a control spring.

The pull on the armature overcomes the spring or gravity and causes it to close when the current in the coil just reaches a certain preset value.

It accomplishes this by activating an auxiliary communication, which triggers a tripping circuit or other desired feature.

Despite its name, this form of relay takes a small but finite amount of time to operate; this is normally taken to be a maximum of 0.2 seconds, but it is often much less. As shown in Figure 1.4 (c), the current/time characteristic

In a single-phase device, a current transformer in one line is connected to the relay coil (see Figure 1.4 (a)), and the value of the current needed to operate the relay is set by the screw adjustment at the top. A current transformer in each step of a three-phase system is attached to one of three relay coils (see Figure 1.4 (b)). The three relay elements may be housed together or separately in an event. In a three-phase, three-wire device, however, any overcurrent in one line is dangerous. An overcurrent in one or both return lines is almost always present. As a consequence, in a 3-wire system, overcurrent relay elements are only needed in two of the three phases to achieve full overcurrent security.

2.3.2 Inverse Time Over current (OCIT) An inverse-time overcurrent relay is shown in the Figure below.

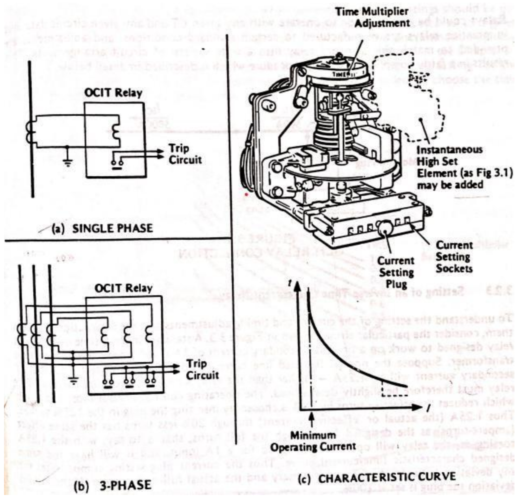

Fig 1.5

It operates on the same induction principle as a household meter. It is made up of a rotating aluminum disc that is driven by a shaded-pole magnet part that receives the driving current from the CT in the circuit to be monitored. The disc spins between the poles of an eddy-current brake magnet, much like a household meter, and is restrained by a light pre-tensioned regulation hairspring. The relay is used with current transformers in single phase or three phase systems, as shown in Figure 1.5 (a) and (b) . As normal current flows from the CT, the disk experiences a moving torque, but the pre-tensioned spring prevents it from rotating

.If the current reaches a certain threshold, the disc begins to rotate and is pushed round against the brake's drag before a contact on the spindle makes contact with a fixed contact. The higher the current excess above this value, the higher the drive torque and the faster the disc attempts to rotate. However, the eddy-current brake's drag increases with rotational speed, and its slowing effect is greatest at high currents. As shown in Figure1.5(c)the combined effect generates a time/current characteristic . The disc does not move at all when the current is less than a certain minimum. The disc shifts when the current exceeds the 'only shift' minimum, and the running time decreases as the current increases—it has a 'inverse-time' characteristic.

This relay's current and time settings can be adjusted in two ways. Set taps on the driving coil are used to change the current. They're normally set by sliding a peg between several holes on the relay face's front. The range is usually between 50% and 200 percent of the normal operating current (1A or 5A depending on the CT used). The time is changed by shifting the fixed contact to increase or decrease the disc's movement until the contacts come into contact. The relay is equipped with either a seconds-based timescale or, more often, a 'time multiplier' modification that is used in combination with curves provided with the relay.

2.3.3 Combined inverse Time Overcurrent and High Set Instantaneous Relay (OCIT/OC)

An inverse time relay can have a second instantaneous part in the same casing, but it must operate at a 'high-set' current value. This gives it the ability to act as both an inverse-time and a high-set instantaneous relay, with the instantaneous feature overriding the time delay only on the most extreme faults. Figure 1.5 shows a dotted example of this additional feature.

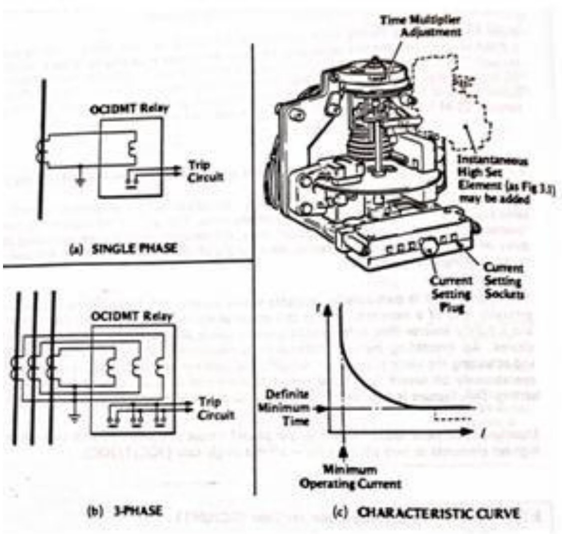

Fig 1.6

When overcurrent security is mounted near the generator end of a network, this configuration is particularly beneficial. Discrimination necessitates the longest delays for this reason, and a strictly inverse-time relay will cause a severe short-circuit to continue until cleared. Such current will be cleaned quickly by an overdriving high-set instantaneous overcurrent relay fed via the same CTs and actuating the same trip circuit. However, it would only work on extreme faults and would not engage in fault currents below its own high threshold. Usually a 3-element OCIT relay (one per phase) would be combined with two instantaneous high-set elements in two phases only – all in a single case (3OCIT/2OC).

2.3.4 Inverse and Definite Minimum Time (OCIDMT)

An inverse and definite minimum time overcurrent relay is shown pictorially in Figure 1.6 the current transformer arrangements with singlephase or 3-phase systems are like those for the simple overcurrent relay and are shown in Figure 1.6 (a) and (b). This relay is simply a variation of the inverse-time type shown in Figure 1.5, but here the characteristic, instead of tending towards zero time for the highest fault currents, now tends towards a definite and finite small value, as in Figure 1.6 (c). this is built into the relay and cannot be adjusted.

The relay is similar in construction to the normal inverse time type shown in Figure 1.5.

The purpose of this variation is to render the relay settings more accurate. All characteristic curves are subject to tolerance, and the separation of the sloping curves of Figure 1.5. at the high-current end for different relays must be enough to allow for such tolerances. Therefore, tripping delays would need to be longer than would be necessary with more accurate curves. The definite minimum time feature at the highest currents, making the curves horizontal at those currents, enables greater accuracy (that is, smaller tolerance) to be achieved, resulting in less separation of the curves and consequently shorter tripping times.

An ACIDMT relay may be combined with instantaneous high-set overcurrent elements as described for an OCIT relay in para. (c) it is shown in dotted outline in Figure 1.6

III. RELAYS IN GENERAL

The majority of protective relays have flags that signify when they have been activated. They show the operator which of the protective systems might have tripped out a turbo-generator, for example. Such relays are usually self-resetting, meaning that once the fault is removed, they return to their original state. This can happen because the circuit breaker has tripped, disconnecting the fault, or because the fault has gone out The flag, on the other hand, remains visible until it is manually reset. All protective relays in some protective systems, especially for generators and transformers, trip the breaker via an intervening hand rest trip, or 'lock-out', relay (TH).. It also has a flag, but once enabled, this relay does not reset itself automatically, preventing the breaker from being reclosed until the relay is manually reset. The breaker stays locked out until the operator resets the lock-out relay, preventing accidental reclosure into a fault. Whenever an item of plant has tripped because one of the protective systems has operated, it is most important that the operator should not reset the relay flags until he has carefully noted down which flags are showing. If this is not done, all evidence of the cause of the malfunction will be lost. The lock-out relay must on no account be reset until it is safe to operate the plant again..

IV. ELECTRONIC RELAYS

Those relays which have so far been described are of the 'electromagnetic' type, where an electromagnet provides the driving force to a mechanical system of moving armature or rotating disc and mechanical contacts. Many of these relays are now being superseded an offshore, and numerous onshore, installations by electronic types which are entirely static except for their final output contacts. Electronic circuits carry out the detection, processing and timing, only the output circuit is passed through normal electromagnetic auxiliary contacts to the external trip circuits. This also isolates the trip circuits proper from the electronics. Though using different methods, electronic relays reproduce similar characteristics to those of the electromechanical types, and they have similar adjustments such as for current and time setting. To illustrate the principle of operation, a single-phase, electronic inverse –time and instantaneous overcurrent relay (OCIT/OC) is described here and shown in Figure below.

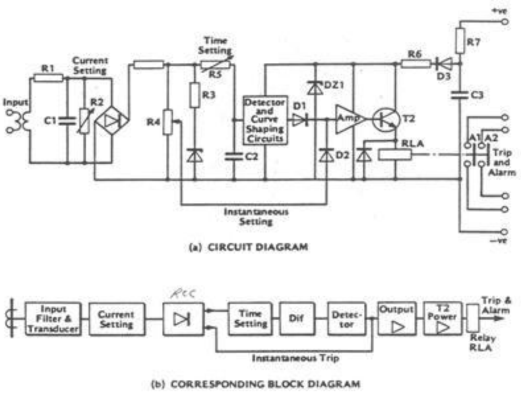

Fig 1.7

The input from the line current transformer is fed through a small adapting transformer to a lowpass filter R1-C1 which suppresses transient voltage surges. A voltage proportional to the input current is developed across the current setting potentiometer R2. this voltage is applied to the bridge rectifier. The d.c. output voltage, which is proportional to the line current, is used to charge the capacitor C2 through the potentiometer R5. The setting of this potentiometer determines the rate at which the voltage across C2 increases and hence the timing of the inverse-time operating characteristic of the relay.

When the voltage across C2 reaches a predetermined value, the detector circuit operates to switch the electromechanical relay, RLA through the output amplifier and power transistor T2. Instantaneous operation is obtained by applying the output voltage of the bridge rectifier directly to the input of the amplifier through R4. thus, for higher values of fault current, the inverse-time delay circuit is bypassed. The power supply for the solid-state circuits is applied through D3 and R6. it is stabilized by Zener diode Dz1, and spike protection is afforded by R7 and C3. the diode D3 protects against reversed polarity of the d.c. power supply. By suitable choice of elements, the electronic relay current/time characteristic can be made to reproduce exactly that of the equivalent electromagnetic type. Having virtually no moving parts, they are, in general, more robust, smaller and lighter. Current and time settings in this case are applied through simple variable resistors.

V. CONCLUSION

Finally, after study the protection devices (fuse, circuit breakers and over current relays).

We find that:

1- protection devices is very essential part of any electrical network or circuit and used to protect both the human and electrical equipment or load.
2- Protection devices which are used in the power system or electrical networks are more than 20 types and we have disused in air subject only three main types.
3- The protection devices which are commonly used in the electrical network are three types (Fuses, Circuit Breakers and over current relays).
4- Circuit breakers are used on both high voltage and low voltage system.
5- The circuit breakers for high voltage system are three types (Oil circuit breakers, Air circuit breakers and Vacuum circuit breakers).
6- The circuit breakers for low voltage systems are three types (Air circuit breakers, Molded case circuit breakers and Miniature circuit breaker) 7- Over current relays consist of four types (Instantaneous over current (OC), Inverse time over current (OCIT), Combined inverse time over current instantaneous relay (OCIT / OC) and Inverse and definite minimum time (OCIDM)).
8- We have learned about the principles of all the previous four types of the over current relays.
9- The principle operation of all types of lover current relay has been described and illustrated.
10- - According to their operation the over current relays are divided into two types

(The electromagnetic types which are old in use and the electronic types which are latest in use).

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